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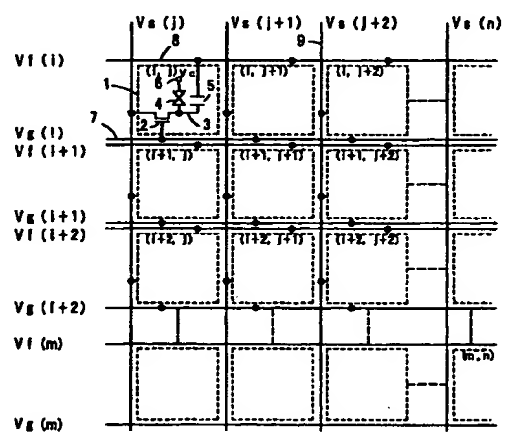
(54) Active matrix liquid crystal display panel and method of driving the same

(57) Conventionally, a modulating voltage for modulating the potential of a pixel electrode through an auxiliary capacitance is superimposed on a scanning signal and applied to a scanning electrode. On the contrary, a modulating electrode for applying a modulating voltage is provided separately from the scanning electrode. Consequently, the amplitude of the scanning signal output from the output IC so as to be applied to the scanning electrode is greatly reduced and the level output is binary, so that the area of the IC chip is greatly reduced. As a result, the cost of the IC is greatly reduced. Moreover, since the modulating electrode is provided below the pixel electrode and no auxiliary capacitance is formed between the pixel electrode and the scanning electrode, the load capacitance of the scanning electrode is reduced, so that the width of the scanning electrode can be reduced to significantly improve the numerical aperture.

Fig. 1



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Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to a liquid crystal display panel in which a TFT (thin film transistor) array is driven to display OA images and video images, and a method of driving the same.

Description of the Prior Art

[0002] Examples of conventional livid crystal display panels include one disclosed in Japanese Laid-open Patent Application No. H2-913. FIG. 8 is a circuit diagram showing the structure of the conventional liquid crystal display panel. In FIG. 8, reference numeral 1 represents a pixel, reference numeral 2 represents a TFT, reference numeral 3 represents a pixel electrode connected to the drain electrode of the TFT 2, reference numeral 4 represents a liquid crystal capacitance formed between a counter electrode 6 and the pixel electrode 3, reference numeral 5 represents an auxiliary capacitance for supplementing the storing property of the liquid crystal capacitance 4, reference numeral 7 represents a scanning electrode connected to the gate electrode of the TFT 2 for supplying a scanning signal to control on and off of the TFT 2, and reference numeral 9 represents a signal electrode connected to the source electrode of the TFT 2 for supplying an image signal to the pixel electrode 3 through the TFT 2.

[0003] FIG. 9 is an equivalent circuit diagram of a pixel (i, j) of the conventional liquid crystal display panel when the TFT 2 is off. In FIG. 9, Cgd represents a gate-drain capacitance between the gate electrode and the drain electrode of the TFT 2, and Csd_1 and Csd_2 represent signal electrode-pixel electrode capacitances between the signal electrode 9 and the pixel electrode 3.

[0004] FIGs. 10(a) to 10(b) are signal waveform charts of the conventional liquid crystal display panel. FIG. 10(a) is a signal waveform chart at the pixel (i, j). FIG. 10(b) is a signal waveform chart at a pixel (i+1, j). FIG. 10(c) is a signal waveform chart at a pixel (i+2, j). In these figures, 1H represents a horizontal scanning period, 1V represents a vertical scanning period, Vc represents a counter signal applied to the counter electrode 6, Vg represents a scanning signal applied to the scanning electrode 7 and supplied to the gate electrode of the TFT 2, Vs represents an image signal applied to the signal electrode 9 and supplied to the source electrode of the TFT 2, Vd represents the potential of the pixel electrode 3 connected to the drain electrode of the TFT 2, Vge+ represents a positive modulating voltage, and Vge- represents a negative modulating voltage. In this conventional display panel, the magnitude of the positive modulating voltage Vge+ is 3 V (=19 V - 16 V), and the magnitude of the negative modulating voltage Vge- is 11 V (=16 V - 5 V).

[0005] With respect to the conventional liquid crystal display panel thus structured, an operation thereof will be described.

[0006] At the pixel (i, j), when the scanning signal Vg(i+1) is on for the 1H period, the image signal Vs(j) is supplied to the pixel electrode 3 serving as one of the electrodes of the liquid crystal capacitance 4 and the auxiliary capacitance 5, so that a predetermined voltage is reached. When the scanning signal Vg(i+1) becomes off, it is attempted to maintain the voltage for the 1V period; however, since the auxiliary capacitance 5 is connected to the preceding scanning electrode 7, when the scanning signal Vg(i) changes to the positive modulating voltage Vge+ or to the negative modulating voltage Vge-, the potential Vd(i, j) of the pixel electrode 3 changes accordingly. Thus, an effective voltage as well as the image signal Vs(j) is applied to the liquid crystal capacitance 4. The same is performed at the pixel (i+1, j) and at the pixel (i+2, j), etc., so that an image is displayed on the entire screen.

[0007] However, in the conventional structure, as shown in FIGs. 10(a) to 10(c), the positive modulating voltage Vge+ and the negative modulating voltage Vge- must be superimposed on the scanning signal Vg, and the modulating voltages necessarily have an amplitude of several tens of volts. Consequently, the output IC for outputting the scanning signal Vg of up to approximately 38 V to the scanning electrode 7 is a process which withstands a very high voltage, and requires a four-value level output, so that the chip area increases. As a result, the cost of the IC significantly increases.

[0008] Moreover, as shown in FIG. 11, since the auxiliary capacitance 5 is formed between the pixel electrode 3 and the scanning electrode 7, the load capacitance of the scanning electrode 7 increases. Further, since the width of the scanning electrode 7 cannot be reduced so much in forming the auxiliary capacitance 5, the numerical aperture is sacrificed. Moreover, the load on the output IC increases as the screen size and the density of the liquid crystal display panel increase, so that the difference in load capacitance between the left and right sides of the screen degrades the display quality.

[0009] Moreover, since pixels in the same row are supplied with the image signal Vs of the see polarity and supplied with the image signal Vs of a different polarity every 1H period, the potential Vd of the pixel electrode 3 is swung through the signal electrode-pixel electrode capacitances Csd_1 and Csd_2 every time the polarity of the image signal Vs changes, so that crosstalk is caused. As a result, the display quality is significantly degraded.

SUMMARY OF THE INVENTION

[0010] An object of the present invention is to provide a liquid crystal display panel and a method of driving the

same in which the output amplitude of the output IC for outputting the scanning signal is restrained, the cost of the IC is greatly reduced by using a low-voltage process, the load capacitance of the scanning electrode is reduced and the numerical aperture is improved.

[0011] Another object of the present invention is to provide a liquid crystal display panel and a method of driving the same in which, in addition to the above-mentioned object, high-quality image display without any crosstalk is realized.

[0012] A liquid crystal display panel of the present invention is a liquid crystal display panel in which a plurality of pixel electrodes are arranged in m rows and in n columns on a light transmitting substrate, m rows of scanning electrodes and n columns of signal electrodes are perpendicularly arranged between the plurality of pixel electrodes, a thin film transistor in which a gate electrode is connected to a scanning electrode in an i-th row (i is an integer among 1 to m), a source electrode is connected to a signal electrode in a j-th column (j is an integer among 1 to n) and a drain electrode is connected to a pixel electrode in the i-th row in the j-th column is disposed at each intersection of the scanning electrode and the signal electrode, and a counter electrode which is opposed to the pixel electrode with liquid crystal between is disposed. The liquid crystal display panel is characterized in that a modulating electrode in the i-th row between which and each of the pixel electrodes in all the columns in the i-th row, an auxiliary capacitance is formed is provided.

[0013] According to this structure, since the modulating electrode between which and each of the pixel electrodes, the auxiliary capacitance is formed is provided separately from the scanning electrode, the amplitude of the scanning signal output from the output IC so as to be applied to the scanning electrode is greatly reduced and the level output is binary, so that the area of the IC chip is greatly reduced. As a result, the cost of the IC is greatly reduced. Moreover, since the auxiliary capacitance is formed not between the pixel electrode and the scanning electrode like in the conventional structure, the load capacitance of the scanning electrode is reduced.

[0014] Further, the liquid crystal display panel is characterized in that the modulating electrode in the i-th row is formed by use of a light transmitting conductive material, and that the modulating electrode in the i-th row is provided between the pixel electrodes in all the columns in the i-th row and the light transmitting substrate with a light transmitting insulating film between the pixel electrodes in all the columns in the i-th row and the modulating electrode in the i-th row.

[0015] Thus, since the modulating electrode using the light transmitting conductive material is provided below the pixel electrode and the load capacitance of the scanning electrode is reduced, the width of the scanning electrode can be reduced to significantly improve the numerical aperture.

[0016] A method of driving a liquid crystal display panel of the present invention is a method of driving the above-described liquid crystal display panel of the present invention, and is characterized in that a potential of the pixel electrode is controlled through the auxiliary capacitance by supplying an image signal whose polarity is reversed every horizontal scanning period to the signal electrode, and applying a positive modulating voltage and a negative modulating voltage to the modulating electrode.

[0017] According to the driving method, since the potential of the pixel electrode is controlled through the auxiliary capacitance by applying a positive modulating voltage and a negative modulating voltage to the modulating electrode, the load capacitance of the scanning electrode is reduced, so that the width of the scanning electrode can be reduced to significantly improve the numerical aperture.

[0018] Moreover, a liquid crystal display panel of the present invention is a liquid crystal display panel in which a plurality of pixel electrodes are arranged in m rows and in n columns on a light transmitting substrate, m rows of scanning electrodes and n columns of signal electrodes are perpendicularly arranged between the plurality of pixel electrodes, a thin film transistor in which a gate electrode is connected to a scanning electrode in an i-th row (i is an integer among 1 to m), a source electrode is connected to a signal electrode in a j-th column (j is an integer among 1 to n) and a drain electrode is connected to a pixel electrode in the i-th row in the j-th column is disposed at each intersection of the scanning electrode and the signal electrode, and a counter electrode which is opposed to the pixel electrode with liquid crystal between is disposed. The liquid crystal display panel is characterized in that the following modulating electrodes are provided: a modulating electrode in a first row between which and the pixel electrode in the first row in a p-th column (p is an odd number or an even number among 1 to n), an auxiliary capacitance is formed; a modulating electrode in a k-th row between which and the pixel electrode in a k-th row in the p-th column (k is an integer among 2 to m) and in the (k-1)-th row in a q-th column (q is an integer other than p among 1 ton), the auxiliary capacitance is formed; and a modulating electrode in an (m+1)-th row between which and the pixel electrode in the m-th row in the q-th column, the auxiliary capacitance is formed.

[0019] According to this structure, since the modulating electrode between which and each of the pixel electrodes, the auxiliary capacitance is formed is provided separately from the scanning electrode, the amplitude of the scanning signal output from the output IC so as to be applied to the scanning electrode is greatly reduced and the level output is binary, so that the area of the IC chip is greatly reduced. As a result, the cost of the IC is greatly reduced. Moreover, since the auxiliary capacitance is formed not between the pixel electrode and the scanning electrode like in the conventional structure,

the load capacitance of the scanning electrode is reduced. Further, since the auxiliary capacitance is formed between the pixel electrode and a different modulating electrode for each column and an image signal whose polarity is reversed for each column of the signal electrode is supplied, the potentials of the pixel electrodes are swung from the signal electrodes on both sides so as to cancel each other through the capacitance between the signal electrodes, so that the potentials of the pixel electrodes are not swung but become stable. As a result, crosstalk disappears and the display quality is significantly improved.

[0020] Further, the liquid crystal display panel is characterized in that the modulating electrodes in the first to the (m+1)-th rows are formed by use of a light transmitting conductive material, the modulating electrode in the first row is provided between the pixel electrode in the first row in the p-th column and the light transmitting substrate with a light transmitting insulating film between the pixel electrode in the first row in the p-th column and the modulating electrode in the first row, the modulating electrode in the k-th row is provided between the pixel electrodes in the k-th row in the p-th column and in the (k-1)th row in the q-th column and the light transmitting substrate with the light transmitting insulating film between the pixel electrodes in the k-th row in the p-th column and in the (k-1)-th row in the q-th column and the modulating electrode in the k-th row, and the modulating electrode in the (m+1)-th row is provided between the pixel electrode in the m-th row in the q-th column and the light transmitting substrate with the light transmitting insulating film between the pixel electrode in the m-th row in the q-th column and the modulating electrode in the (m+1)-th row.

[0021] Thus, since the modulating electrode using the light transmitting conductive material is provided below the pixel electrode and the load capacitance of the scanning electrode is reduced, the width of the scanning electrode can be reduced to significantly improve the numerical aperture.

[0022] Moreover, a method of driving a liquid crystal display panel of the present invention is a method of driving the above-described liquid crystal display panel of the present invention, and is characterized in that a potential of the pixel electrode is controlled through the auxiliary capacitance by supplying an image signal whose polarity is reversed every column of the n columns of the signal electrodes, supplying the image signal whose polarity is reversed every horizontal scanning period to the same signal electrode, and applying a positive modulating voltage and a negative modulating voltage to the modulating electrode.

[0023] According to the driving method, since the potential of the pixel electrode is controlled through the auxiliary capacitance by applying a positive modulating voltage and a negative modulating voltage to the modulating electrode, the load capacitance of the scanning electrode is reduced, so that the width of the scanning electrode can be reduced to significantly improve the numerical aperture. Further, since the image signal whose polarity is reversed every column of the signal electrode is supplied, the potentials of the image electrodes are swung from the signal electrodes on both sides so as to cancel each other through the capacitance between the signal electrodes, so that the potentials of the pixel electrodes are not swung but become stable. As a result, crosstalk disappears and the display quality is significantly improved.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024]

FIG. 1 is a circuit diagram showing the structure of a liquid crystal display panel according to a first embodiment of the present invention;
FIGs. 2(a) and 2(b) are a plan view and a cross-sectional view, respectively, showing the structure of an auxiliary capacitance of the liquid crystal display panel according to the first embodiment of the present invention;
FIGs. 3(a) to 3(c) are signal waveform charts of the liquid crystal display panel according to the first embodiment of the present invention;
FIG. 4 is a circuit diagram showing the structure of a liquid crystal display panel according to a second embodiment of the present invention;
FIGs. 5(a) and 5(b) are a plan view and a cross-sectional view, respectively, showing the structure of the auxiliary capacitance of the liquid crystal display panel according to the second embodiment of the present invention;
FIG. 6 is an equivalent circuit diagram of the pixel (i, j) of the liquid crystal display panel according to the second embodiment of the present invention when a TFT is off;
FIGs. 7(a) to (f) are signal waveform charts of the liquid crystal display panel according to the second embodiment of the present invention;
FIG. 8 is a circuit diagram showing the structure of the conventional liquid crystal display panel;
FIG. 9 is an equivalent circuit diagram of the pixel (i, j) of the conventional liquid crystal display panel when the TFT is off;
FIGs. 10(a) to 10(c) are signal waveform charts of the conventional liquid crystal display panel; and
FIG. 11 is a plan view showing the structure of the auxiliary capacitance of the conventional liquid crystal display panel.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0025] Preferred embodiments of the present invention will be described with reference to the drawings.

(First Embodiment)

[0026] FIG. 1 is a circuit diagram showing the structure of a liquid crystal display panel according to a first embodiment of the present invention. In FIG. 1, reference numeral 1 represents a pixel, reference numeral 2 represents a TFT, reference numeral 3 represents a pixel electrode connected to the drain electrode of the TFT 2, reference numeral 4 represents a liquid crystal capacitance formed between a counter electrode 6 and the pixel electrode 3, reference numeral 5 represents an auxiliary capacitance for supplementing the storing property of the liquid crystal capacitance 4, reference numeral 7 represents a scanning electrode connected to the gate electrode of the TFT 2 for supplying a scanning signal to control on and off of the TFT 2, and reference numeral 9 represents a signal electrode connected to the source electrode of the TFT 2 for supplying an image signal to the pixel electrode 3 through the TFT 2. These elements are similar to those of the conventional liquid crystal display panel and denoted by the same reference numerals as those of FIG. 8. Reference numeral 8 represents a modulating electrode for modulating the potential of the pixel electrode 3.

[0027] This embodiment is different from the conventional structure in that the modulating electrode 8 for applying a modulating signal Vf to modulate the potential Vd of the pixel electrode 3 through the auxiliary capacitance 5 is provided separately from the scanning electrode 7. That is, the auxiliary capacitance 5 is provided not between the pixel electrode 3 and the scanning electrode 7 like in the conventional structure but between the pixel electrode 3 and the modulating electrode 8 in this embodiment.

[0028] The structure of the auxiliary capacitance 5 in this embodiment is shown in FIGs. 2(a) and 2(b). FIG. 2(a) is a plan view showing the structure of the auxiliary capacitance 5. FIG. 2(b) is a cross-sectional view taken on the line A-A of FIG. 2(a). In these figures, the TFT 2 is not illustrated but shown being simplified. As shown in the figures, the auxiliary capacitance 5 is formed by providing the modulating electrode 8, with a light transmitting insulating film 12 between, below the pixel electrode 3 disposed on a light transmitting substrate 11. Therefore, after the modulating electrode 8 is formed on the light transmitting substrate 11, the light transmitting insulating film 12 is formed on the entire surface, and the pixel electrode 3, the scanning electrode 7 and the signal electrode 9, etc. are formed on the light transmitting insulating film 12. The pixel electrode 3 and the modulating electrode 8 are made of a light transmitting conductive material such as ITO (indium-tin oxide) which a transparent electrode can be formed of. The light transmitting substrate 11 comprises a substrate having light transmitting capability such as glass. The light transmitting insulating film 12 comprises a silicon oxide film (SiO_2), a tantalum oxide film (Ta_2O_3) or a silicon nitride film (SiNox).

[0029] FIGs. 3(a) to 3(c) are signal waveform charts of the liquid crystal display panel according to the first embodiment. FIG. 3(a) is a signal waveform chart at the pixel (i, j). FIG. 3(b) is a signal waveform chart at a pixel (i+1, j). FIG. 3(c) is a signal waveform chart at a pixel (i+2, j). In these figures, 1H represents a horizontal scanning period, 1V represents a vertical scanning period, Vc represents a counter signal applied to the counter electrode 6, Vg represents a scanning signal applied to the scanning electrode 7 and supplied to the gate electrode of the TFT 2, Vs represents an image signal applied to the signal electrode 9 and supplied to the source electrode of the TFT 2, Vd represents the potential of the pixel electrode 3 connected to the drain electrode of the TFT 2, Vf represents a modulating signal applied to the modulating electrode 8 and having a positive modulating voltage Vge+ and a negative modulating voltage Vge-. The magnitude of the modulating voltage Vge+ is 3 V, and the magnitude of the modulating voltage Vge- is 11 V (=14 V - 3 V). These magnitudes are the same as those of the conventional display panel. During a period of 1V, the modulating signal Vf changes by the magnitude of the voltage Vge- in the 1H period immediately after the scanning signal Vg becomes on, is constant until the next 1H period immediately before the scanning signal Vg becomes on the next time, and then, changes by the magnitude of (Vge-)-(Vge+). During the next 1V period, the modulating signal Vf changes by the magnitude of Vge+ in the 1H period immediately after the scanning signal becomes on.

[0030] With respect to the liquid crystal display panel according to the first embodiment thus structured, an operation thereof will be described.

[0031] At the pixel (i, j), when the scanning signal Vg(i) is on for the 1H period, the image signal Vs(j) is supplied to the pixel electrode 3 serving as one of the electrodes of the liquid crystal capacitance 4 and the auxiliary capacitance 5, so that a predetermined voltage is reached. When the scanning signal Vg(i) becomes off, it is attempted to maintain the voltage for the 1V period; however, since the auxiliary capacitance 5 is connected to the modulating electrode 8, when the modulating signal Vf(i) changes to the positive modulating voltage Vge+ or to the negative modulating voltage Vge-, the potential Vd(i, j) of the pixel electrode 3 changes accordingly. Thus, an effective voltage as well as the image signal Vs(j) is applied to the liquid crystal capacitance 4. The same is performed at the pixel (i+1, j) and at the pixel (i+2, j), etc., so that an image is displayed on the entire screen.

[0032] In the conventional display panel, the output IC for outputting the scanning signal Vg to the scanning electrode 7 is a process which withstands a very high voltage (approximately 38 V) and requires a four-value level output. However, in this embodiment, since the modulating electrode 8 for applying the modulating signal Vf is provided separately from the scanning elec-

trode 7, the amplitude of the scanning signal Vg output from the output IC is greatly reduced to approximately 2 V and the level output is binary, so that the area of the IC chip is greatly reduced. As a result, the cost of the IC is greatly reduced. With respect to the modulating signal Vf, the amplitude is approximately 11 V.

[0033] Moreover, by forming the auxiliary capacitance 5 not between the pixel electrode 3 and the scanning electrode 7 like in the conventional structure but between the pixel electrode 3 and the modulating electrode 8 provided below the pixel electrode 3 with the light transmitting insulating film 12 between as shown in Fig. 2(b), the load capacitance of the scanning electrode 7 is reduced, so that the width of the scanning electrode 7 can be reduced to significantly improve the numerical aperture.

(Second Embodiment)

[0034] FIG. 4 is a circuit diagram showing the structure of a liquid crystal display panel according to a second embodiment of the present invention. In FIG. 4, reference numeral 2 represents a TFT, reference numeral 3 represents a pixel electrode, reference numeral 4 represents a liquid crystal capacitance, reference numeral 5 represents an auxiliary capacitance, reference numeral 6 represents a counter electrode, reference numeral 7 represents a scanning electrode, reference numeral 8 represents a modulating electrode, and reference numeral 9 represents a signal electrode. These elements are similar to those of the first embodiment and denoted by the same reference numerals as those of FIG. 1. In FIG. 4, pixels in odd-numbered columns are denoted by 1 and pixels in even-numbered columns are denoted by 10.

[0035] This embodiment is similar to the first embodiment in that the modulating electrode 8 for applying the modulating signal Vf to modulate the potential Vd of the pixel electrode 3 through the auxiliary capacitance 5 is provided separately from the scanning electrode 7. In the second embodiment, the auxiliary capacitances 5 in the pixels 1 in odd-numbered columns and those in the pixels 10 in even-numbered columns are connected to the modulating electrodes 8 in different rows. Therefore, the number of modulating electrodes 8 is greater by one than the number of scanning electrodes 7. The polarity of the image signal Vs supplied to the signal electrodes 9 in odd-numbered columns and that supplied to the electrodes 9 in even-numbered columns are opposite to each other.

[0036] The structure of the auxiliary capacitance 5 in this embodiment is shown in FIGs. 5(a) and 5(b). FIG. 5(a) is a plan view showing the structure of the auxiliary capacitance 5. FIG. 5(b) is a cross-sectional view taken on the line B-B of FIG. 5(a). In these figures, the TFT 2 is not illustrated but shown being simplified. As shown in the figures, the auxiliary capacitance 5 is formed by providing the modulating electrode 8, with a light transmitting insulating film 12 between, below the pixel electrode 3 disposed on the light transmitting substrate 11. Therefore, after the modulating electrode 8 is formed on the light transmitting substrate 11, the light transmitting insulating film 12 is formed on the entire surface, and the pixel electrode 3, the scanning electrode 7 and the signal electrode 9, etc. are formed on the light transmitting insulating film 12. The elements such as the pixel electrode 3, the modulating electrode 8, the light transmitting substrate 11 and the light transmitting insulating film 12 are made of a similar material to those of the first embodiment. This embodiment is different from the first embodiment in the plane configuration of the modulating electrode 8.

[0037] FIG. 6 is an equivalent circuit diagram of the pixel (i, j) of the liquid crystal display panel according to the second embodiment of the present invention when the TFT 2 is off. In FIG. 6, Cgd represents a gate-drain capacitance between the gate electrode and the drain electrode of the TFT 2, and Csd_1 and Csd_2 represent signal electrode-pixel electrode capacitances between the signal electrode 9 and the pixel electrode 3.

[0038] FIGs. 7(a) to 7(b) are signal waveform charts of the liquid crystal display panel according to the second embodiment. FIG. 7(a) is a signal waveform chart at the pixel (i, j). FIG. 7(b) is a signal waveform chart at the pixel (i+1, j). FIG. 7(c) is a signal waveform chart at the pixel (i+2, j). FIG. 7(d) is a signal waveform chart at a pixel (i, j+1). FIG. 7(e) is a signal waveform chart at a pixel (i+1, j+1). FIG. 7(f) is a signal waveform chart at a pixel (i+2, j+1). In these figures, 1H represents a horizontal scanning period, 1V represents a vertical scanning period, Vc represents a counter signal, Vg represents a scanning signal, Vs represents an image signal, Vd represents the potential of the pixel electrode 3, Vf represents a modulating signal, Vge+ represents a positive modulating voltage, and Vge- represents a negative modulating voltage.

[0039] The application period of the modulating voltages Vge+ and Vge- is shifted by the 1H period between FIGs. 7(a) to (c) and 7(d) to 7(f). With respect to the pixels in the j-th column, the auxiliary capacitance 5 of, for example, the pixel (i, j) in the i-th row is connected to the modulating electrode 8 in the i-th row, whereas with respect to the pixels in the (j+1)-th column, the auxiliary capacitance 5 of, for example, the pixel (i, j+1) in the i-th row is connected to the modulating electrode 8 in the (i+1)-th row. The modulating electrode 8 in the (i+1)-th row is the modulating electrode 8 connected to the auxiliary capacitance 5 of the pixel (i+1, j) in the (i+1)-th row among the pixels in the j-th column. Thus, in the pixels in odd-numbered columns and the pixels in even-numbered columns, a common modulating electrode 8 is used as the auxiliary capacitances of pixels in rows different from each other by one row, so that a shift of the 1H period is caused during the application period of the modulating voltages Vge+ and Vge-. However, this does not cause a large problem because

it is a shift of the 1H period during the 1V period.

[0040] With respect to the liquid crystal display panel according to the second embodiment thus structured, an operation thereof will be described.

[0041] First, the case of the pixels 1 in odd-numbered column will be described. For example, at the pixel (i, j), when the scanning signal Vg(i) is on for the 1H period, the image signal Vs(j) is supplied to the pixel electrode 3 serving as one of the electrodes of the liquid crystal capacitance 4 and the auxiliary capacitance 5, so that a predetermined voltage is reached. When the scanning signal Vg(i) becomes off, it is attempted to maintain the voltage for the 1V period; however, since the auxiliary capacitance 5 is connected to the modulating electrode 8, when the modulating signal Vf(i) changes to the positive modulating voltage Vge+ or to the negative modulating voltage Vge-, the potential Vd(i, j) of the pixel electrode 3 changes accordingly. Thus, an effective voltage as well as the image signal Vs(j) is applied to the liquid crystal capacitance 4. The same is performed at the pixel (i+1, j) and at the pixel (i+2, j), etc.

[0042] Next, the case of the pixels 10 in even-numbered columns will be described. For example, at the pixel (i, j+1), when the scanning signal Vg(i) is on for the 1H period, a reversed image signal/Vs(j+1) is supplied to the pixel electrode 3 serving as one of the electrodes of the liquid crystal capacitance 4 and the auxiliary capacitance 5, so that a predetermined voltage is reached. When the scanning signal Vg(i) becomes off, it is attempted to maintain the voltage for the 1V period; however, since the auxiliary capacitance 5 is connected to the modulating electrode 8, when the modulating signal Vf(i+1) changes to the positive modulating voltage Vge+ or to the negative modulating voltage Vge-, the potential Vd(i, j+1) of the pixel electrode 3 changes accordingly. Thus, an effective voltage as well as the reversed image signal/Vs(j+1) is applied to the liquid crystal capacitance 4. The same is performed at the pixel (i+1, j+1) and at the pixel (i+2, j+1), etc., so that an image is displayed on the entire screen.

[0043] As described above, according to this embodiment, by providing the modulating electrode 8 for applying the modulating signal Vf separately from the scanning electrode 7 like in the first embodiment, the amplitude of the scanning signal Vg output from the output IC is greatly reduced and the level output is binary, so that the area of the IC chip is greatly reduced. As a result, the cost of the IC is greatly reduced.

[0044] Moreover, by forming the auxiliary capacitance 5 not between the pixel electrode 3 and the scanning electrode 7 like in the conventional display panel but between the pixel electrode 3 and the modulating electrode 8 provided below the pixel electrode 3 with the light transmitting insulating film 12 between as shown in FIGs. 5(a) and 5(b), the load capacitance of the scanning electrode 7 is reduced, so that the width of the scanning electrode 7 can be reduced to significantly improve the numerical aperture.

[0045] Further, according to this embodiment, since the auxiliary capacitance 5 connected to the pixel electrode 3 is formed between the pixel electrode 3 and a modulating electrode 8 which differs for each column and the polarity of the image signal Vs applied to the signal electrodes 9 in odd-numbered columns and that applied to the electrodes 9 in even-numbered columns are opposite to each other, the potentials Vd of the pixel electrodes 3 are swung so as to cancel each other through adjoining signal electrode-pixel electrode capacitances Csd_1 and Csd_2, so that the potentials Vd of the pixel electrodes 3 are not swung but become stable. As a result, crosstalk disappears and the display quality is significantly improved.

[0046] While the scanning signal Vg, the image signal Vs and the modulating signal Vf are supplied to the electrodes in the description given above, the present invention can be embodied when these signals are all generated in an incorporated IC and supplied or are separately generated in an external IC and supplied.

[0047] While description has been given with respect to the pixel-by-pixel structure in the first and second embodiments, similar effects are obtained in the case of a structure per RGB.

[0048] Conventionally, a modulating voltage for modulating the potential of a pixel electrode through an auxiliary capacitance is superimposed on a scanning signal and applied to a scanning electrode. On the contrary, a modulating electrode for applying a modulating voltage is provided separately from the scanning electrode. Consequently, the amplitude of the scanning signal output from the output IC so as to be applied to the scanning electrode is greatly reduced and the level output is binary, so that the area of the IC chip is greatly reduced. As a result, the cost of the IC is greatly reduced. Moreover, since the modulating electrode is provided below the pixel electrode and no auxiliary capacitance is formed between the pixel electrode and the scanning electrode, the load capacitance of the scanning electrode is reduced, so that the width of the scanning electrode can be reduced to significantly improve the numerical aperture.

Claims

1. A liquid crystal display panel in which a plurality of pixel electrodes are arranged in m rows and in n columns on a light transmitting substrate, m rows of scanning electrodes and n columns of signal electrodes are perpendicularly arranged between said plurality of pixel electrodes, a thin film transistor in which a gate electrode is connected to a scanning electrode in an i-th row (i is an integer among 1 to m), a source electrode is connected to a signal electrode in a j-th column (j is an integer among 1 to n) and a drain electrode is connected to a pixel electrode in the i-th row in the j-th, column is disposed at each intersection of said scanning elec-

trode and said signal electrode, and a counter electrode which is opposed to said pixel electrode with liquid crystal between is disposed,

wherein a modulating electrode in the i-th row is provided between which and each of said pixel electrodes in all the columns in the i-th row, an auxiliary capacitance is formed.

2. A liquid crystal display panel according to claim 1, wherein said modulating electrode in the i-th row is formed by use of a light transmitting conductive material, and said modulating electrode in the i-th row is provided between the pixel electrodes in all the columns in the i-th row and the light transmitting substrate with a light transmitting insulating film between the pixel electrodes in all the columns in the i-th row and the modulating electrode in the i-th row.

3. A liquid crystal display panel in which a plurality of pixel electrodes are arranged in m rows and in n columns on a light transmitting substrate, m rows of scanning electrodes and n columns of signal electrodes are perpendicularly arranged between said plurality of pixel electrodes, a thin film transistor in which a gate electrode is connected to a scanning electrode in an i-th row (i is an integer among 1 to m), a source electrode is connected to a signal electrode in a j-th column (j is an integer among 1 to n) and a drain electrode is connected to a pixel electrode in the i-th row in the j-th column is disposed at each intersection of said scanning electrode and said signal electrode, and a counter electrode which is opposed to said pixel electrode with liquid crystal between is disposed,

wherein the following modulating electrodes are provided: a modulating electrode in a first row between which and said pixel electrode in the first row in a p-th column (p is an odd number or an even number among 1 to n), an auxiliary capacitance is formed; a modulating electrode in a k-th row between which and said pixel electrode in a k-th row in the p-th column (k is an integer among 2 to m) and in the (k-1)-th row in a q-th column (q is an integer other than p among 1 to n), the auxiliary capacitance is formed; and a modulating electrode in an (m+1)-th row between which and said pixel electrode in the m-th row in the q-th column, the auxiliary capacitance is formed.

4. A liquid crystal display panel according to claim 3, wherein said modulating electrodes in the first to the (m+1)-th rows are formed by use of a light transmitting conductive material, said modulating electrode in the first row is provided between the pixel electrode in the first row in the p-th column and the light transmitting substrate with a light transmitting insulating film between the pixel electrode in the first row in the p-th column and the modulating electrode in the first row, said modulating electrode in the k-th row is provided between the pixel electrodes in the k-th row in the p-th column and in the (k-1)th row in the q-th column and the light transmitting substrate with the light transmitting insulating film between the pixel electrodes in the k-th row in the p-th column and in the (k-1)-th row in the q-th column and the modulating electrode in the k-th row, and said modulating electrode in the (m+1)-th row is provided between the pixel electrode in the m-th row in the q-th column and the light transmitting substrate with the light transmitting insulating film between the pixel electrode in the m-th row in the q-th column and the modulating electrode in the (m+1)-th row.

5. A method of driving said liquid crystal display panel according to claim 1 or 2, wherein a potential of the pixel electrode is controlled through the auxiliary capacitance by supplying an image signal whose polarity is reversed every horizontal scanning period to the signal electrode, and applying a positive modulating voltage and a negative modulating voltage to the modulating electrode.

6. A method of driving said liquid crystal display panel according to claim 3 or 4, wherein a potential of the pixel electrode is controlled through the auxiliary capacitance by supplying an image signal whose polarity is reversed every column of the n columns of the signal electrodes, supplying the image signal whose polarity is reversed every horizontal scanning period to the same signal electrode, and applying a positive modulating voltage and a negative modulating voltage to the modulating electrode.

Fig. 1

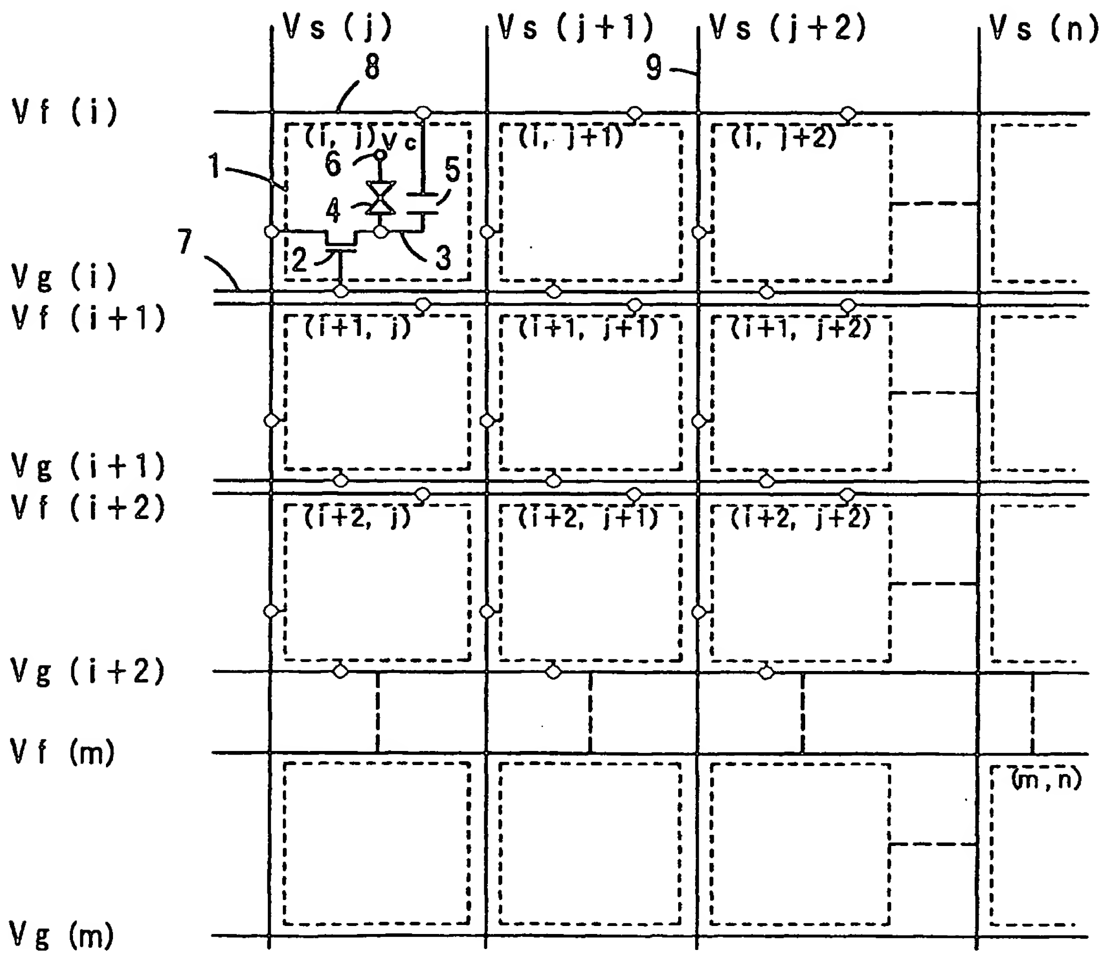
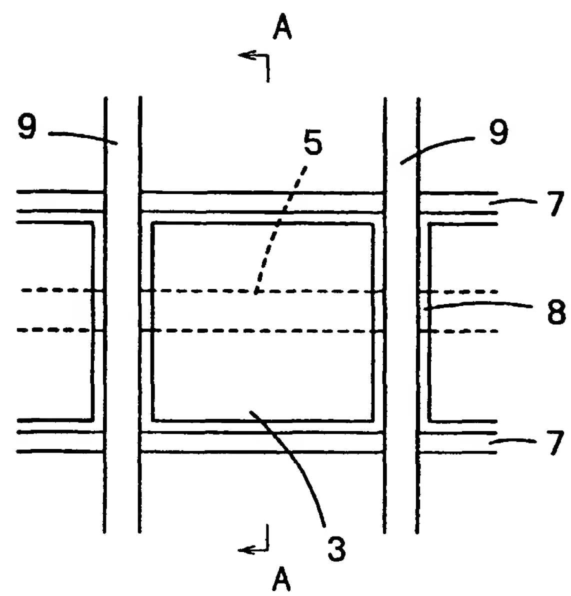

Vs (j)
Vs (j+1)
Vs (j+2)
Vs (n)
8
9
Vf (i)
(i, j)
Vc
6
5
1
4
7
2
3
Vg (i)
Vf (i+1)
(i, j+1)
(i, j+2)
(i+1, j)
(i+1, j+1)
(i+1, j+2)
Vg (i+1)
Vf (i+2)
(i+2, j)
(i+2, j+1)
(i+2, j+2)
Vg (i+2)
Vf (m)
(m, n)
Vg (m)

Fig. 2

(a)



(b)

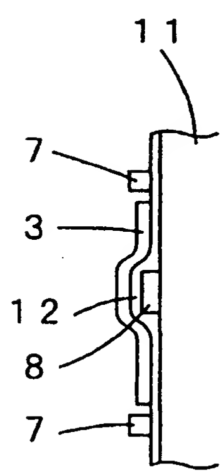


Fig. 3

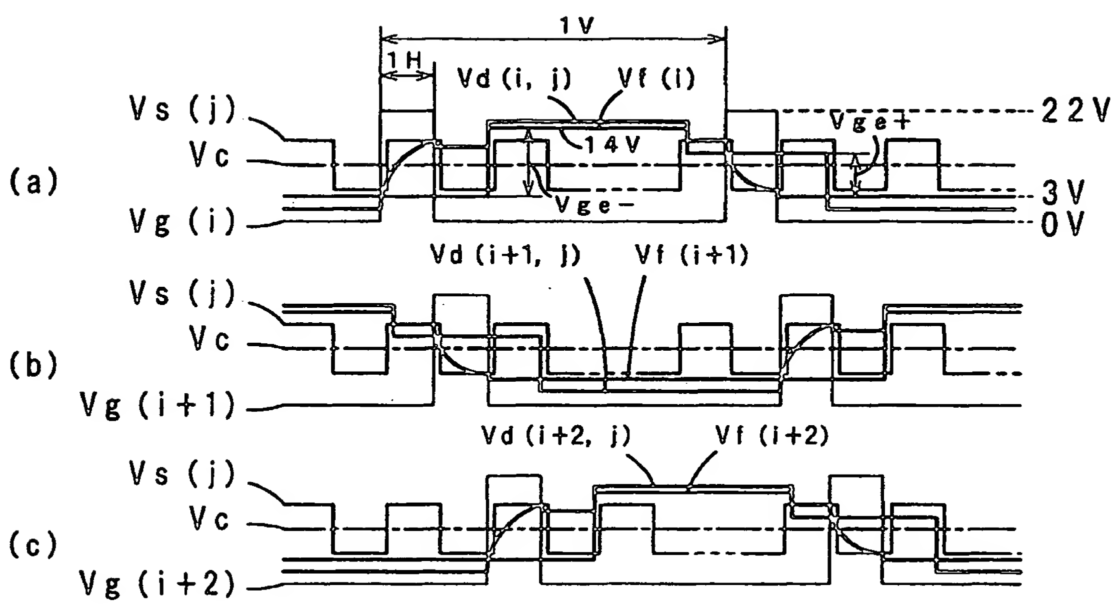

1V
1H
Vd (i, j)
Vf (i)
Vs (j)
Vc
(a)
Vg (i)
14V
Vge−
Vge+
22V
3V
0V
Vd (i+1, j)
Vf (i+1)
Vs (j)
Vc
(b)
Vg (i+1)
Vd (i+2, j)
Vf (i+2)
Vs (j)
Vc
(c)
Vg (i+2)

Fig. 4

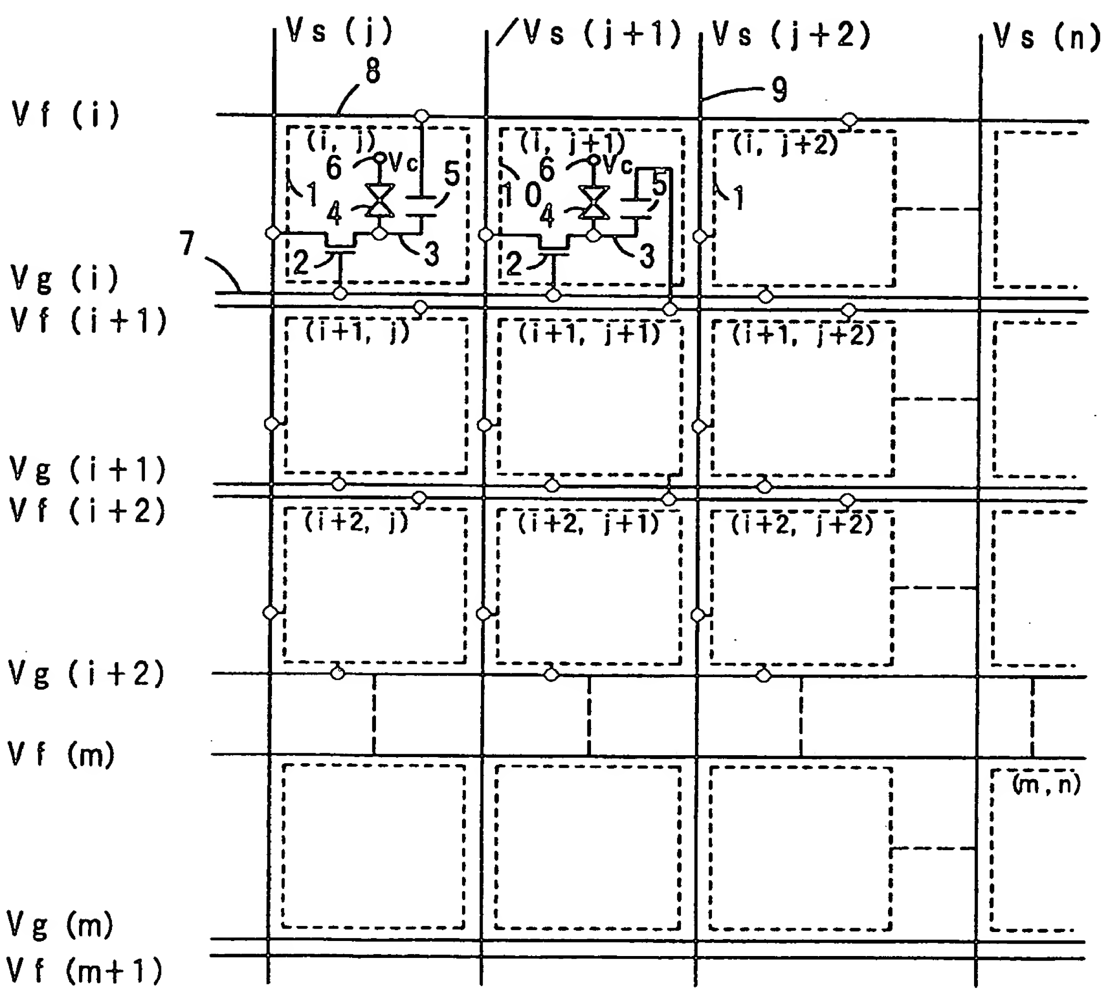
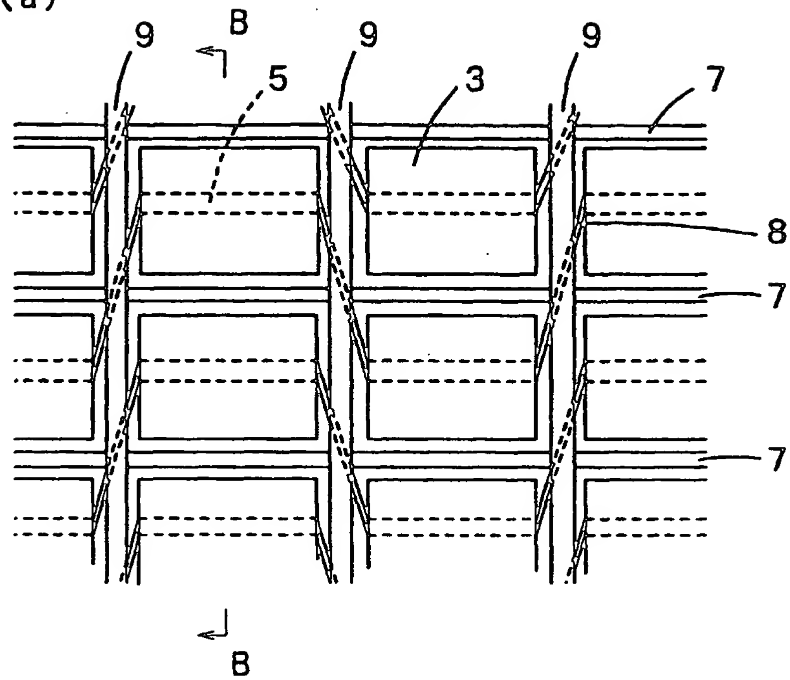

Vs (j)
/Vs (j+1)
Vs (j+2)
Vs (n)
8
9
Vf (i)
(i, j)
(i, j+1)
(i, j+2)
6
Vc
5
1
4
3
2
7
10
Vg (i)
Vf (i+1)
(i+1, j)
(i+1, j+1)
(i+1, j+2)
Vg (i+1)
Vf (i+2)
(i+2, j)
(i+2, j+1)
(i+2, j+2)
Vg (i+2)
Vf (m)
(m, n)
Vg (m)
Vf (m+1)

Fig. 5

(a)



(b)

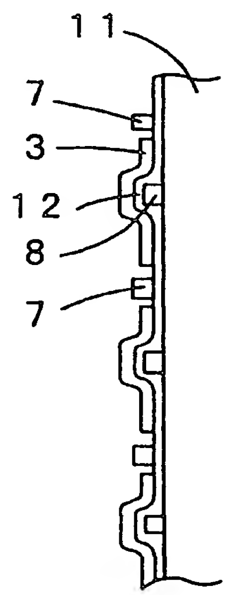


Fig. 6

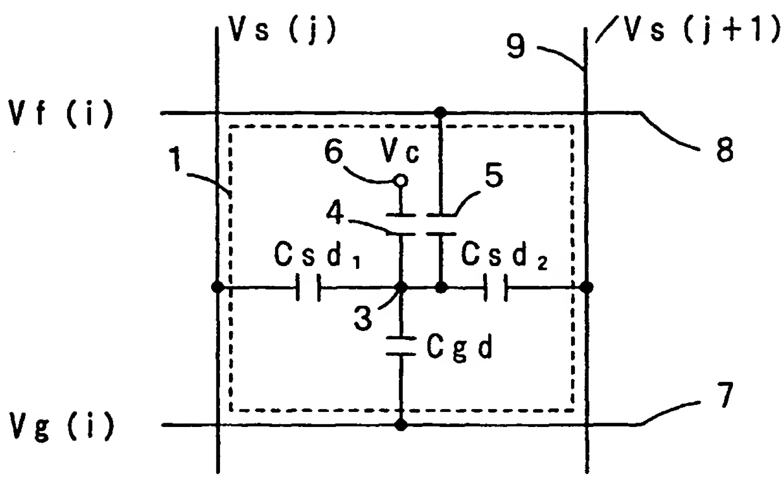


Fig. 7

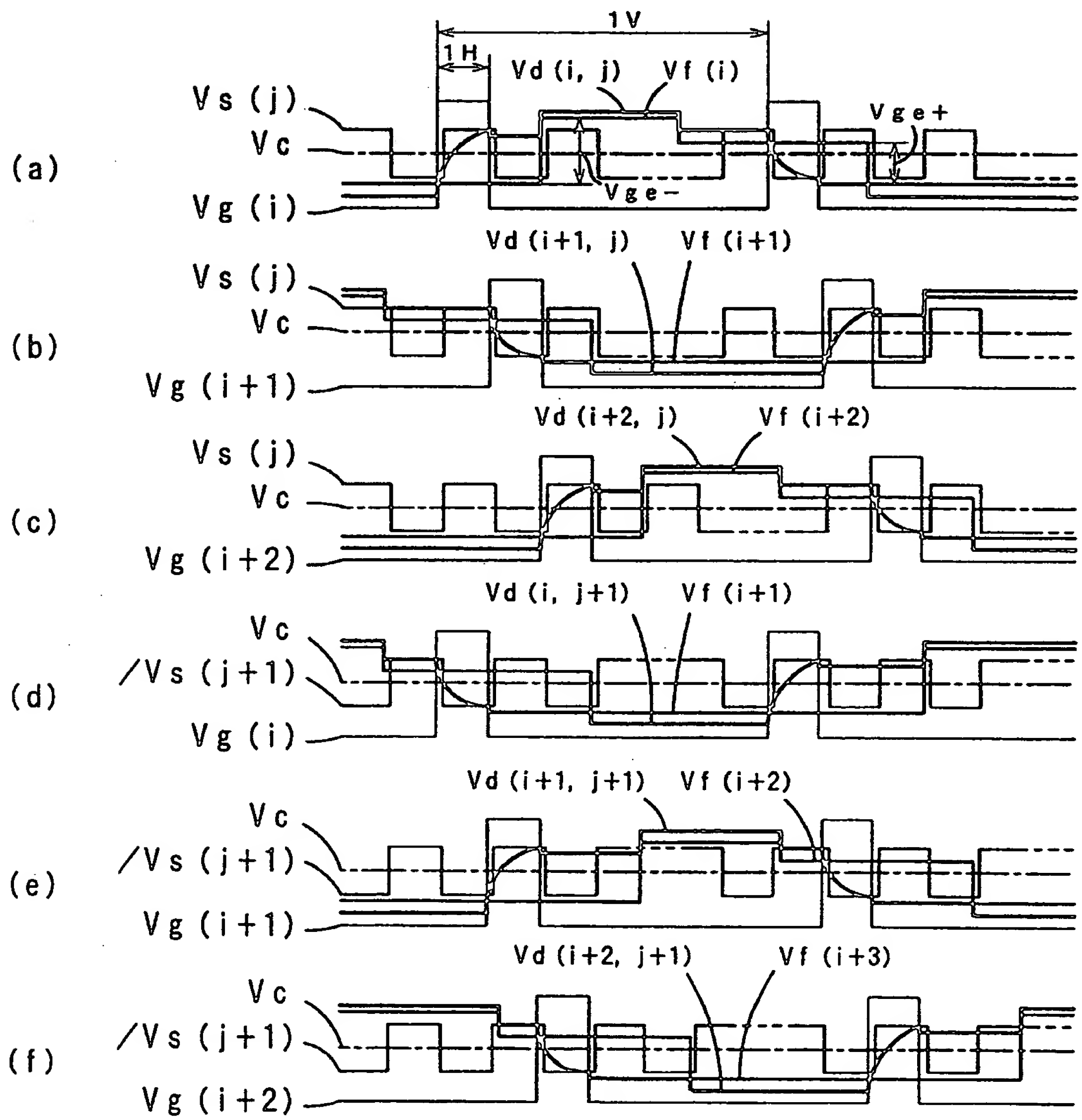

1V
1H
Vd (i, j)
Vf (i)
Vs (j)
Vc
Vge+
(a)
Vge−
Vg (i)
Vd (i+1, j)
Vf (i+1)
Vs (j)
Vc
(b)
Vg (i+1)
Vd (i+2, j)
Vf (i+2)
Vs (j)
Vc
(c)
Vg (i+2)
Vd (i, j+1)
Vf (i+1)
Vc
/Vs (j+1)
(d)
Vg (i)
Vd (i+1, j+1)
Vf (i+2)
Vc
/Vs (j+1)
(e)
Vg (i+1)
Vd (i+2, j+1)
Vf (i+3)
Vc
/Vs (j+1)
(f)
Vg (i+2)

Fig. 8

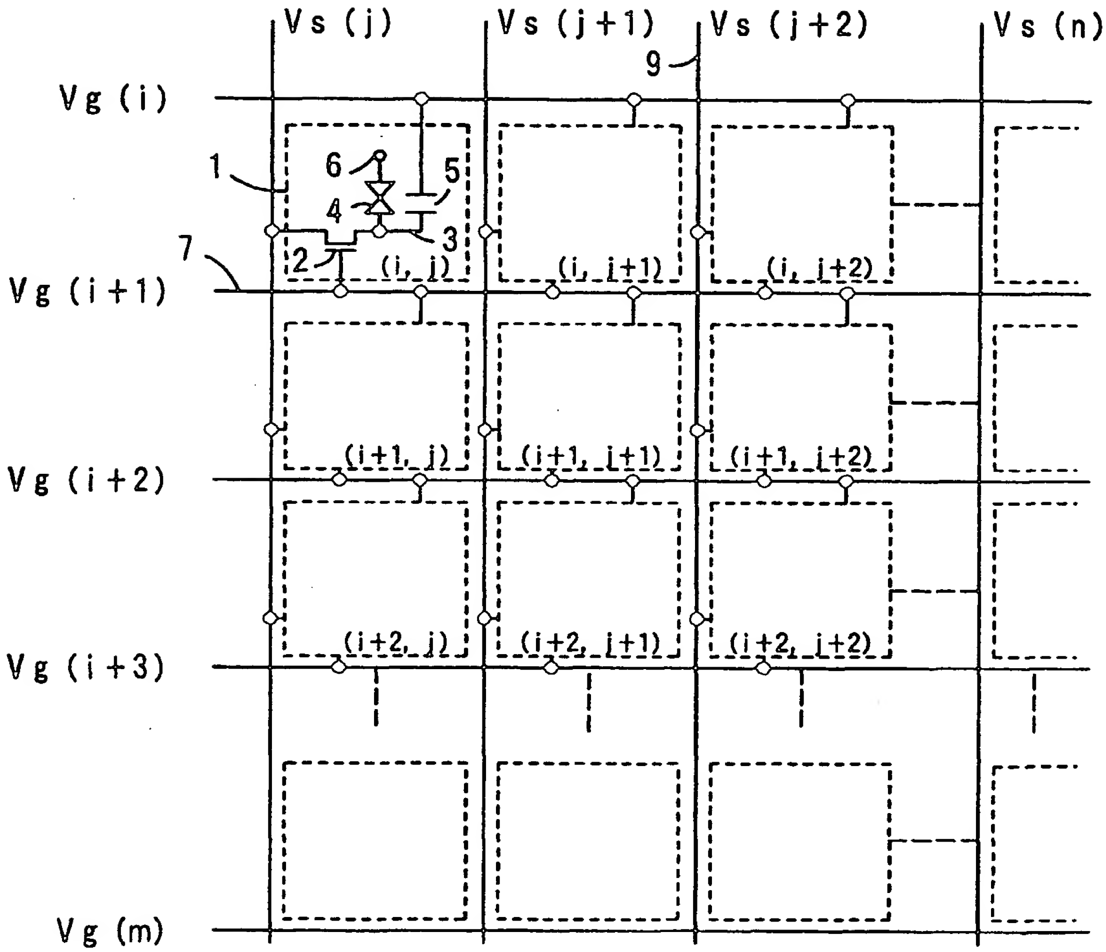

Vs (j)
Vs (j+1)
Vs (j+2)
Vs (n)
9
Vg (i)
Vg (i+1)
Vg (i+2)
Vg (i+3)
Vg (m)
1
2
3
4
5
6
7
(i, j)
(i, j+1)
(i, j+2)
(i+1, j)
(i+1, j+1)
(i+1, j+2)
(i+2, j)
(i+2, j+1)
(i+2, j+2)

Fig. 9

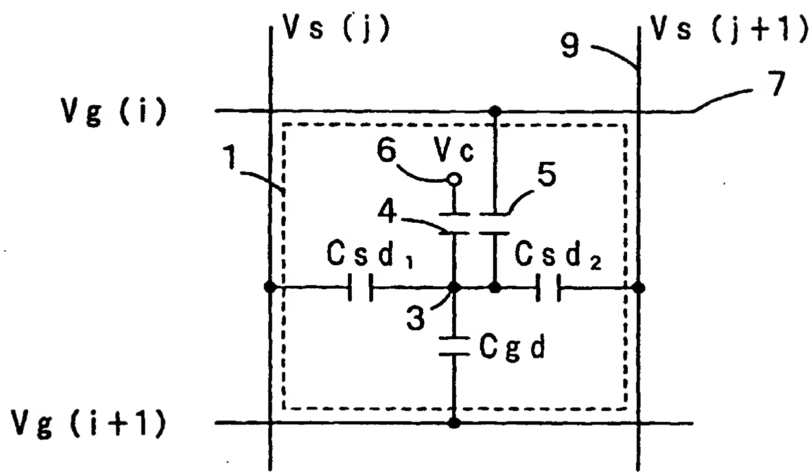


Fig. 10

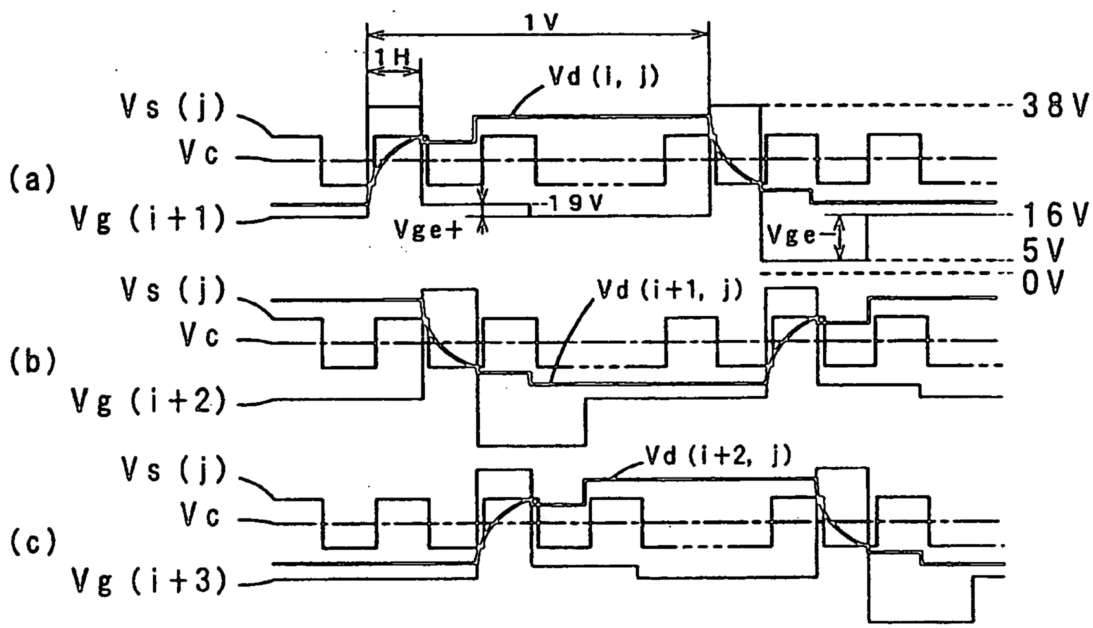

1V
1H
Vd (i, j)
Vs (j)
Vc
(a)
Vg (i+1)
-19V
Vge+
Vge-
38V
16V
5V
0V
Vs (j)
Vd (i+1, j)
Vc
(b)
Vg (i+2)
Vs (j)
Vd (i+2, j)
Vc
(c)
Vg (i+3)

Fig. 11